

Atlantic Ocean is headed for a tipping point – once melting glaciers shut down the Gulf Stream, we would see extreme climate change within decades, study shows

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Too much fresh water from Greenland's ice sheet can slow the Atlantic Ocean's circulation. Paul Souders/Stone via Getty Images

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Superstorms, abrupt climate shifts and New York City frozen in ice. That's how the blockbuster Hollywood movie 'The Day After Tomorrow' depicted an abrupt shutdown of the Atlantic Ocean's circulation and the catastrophic consequences.

While Hollywood's vision was over the top, the 2004 movie raised a serious question: If global warming shuts down the Atlantic Meridional Overturning Circulation, which is crucial for carrying heat from the tropics to the northern latitudes, how abrupt and severe would the climate changes be?

Twenty years after the movie's release, we know a lot more about the Atlantic Ocean's circulation. Instruments deployed in the ocean starting in 2004 show that the Atlantic Ocean circulation has observably slowed over the past two decades, possibly to its weakest state in almost a millennium. Studies also suggest that the circulation has reached a dangerous tipping point in the past that sent it into a precipitous, unstoppable decline, and that it could hit that tipping point again as the planet warms and glaciers and ice sheets melt.

In a new study using the latest generation of Earth's climate models, we simulated the flow of fresh water until the ocean circulation reached that tipping point.

The results showed that the circulation could fully shut down within a century of hitting the tipping point, and that it's headed in that direction. If that happened, average temperatures would drop by several degrees in North America, parts of Asia and Europe, and people would see severe and cascading consequences around the world.

We also discovered a physics-based early warning signal that can alert the world when the Atlantic Ocean circulation is nearing its tipping point.

The ocean's conveyor belt

Ocean currents are driven by winds, tides and water density differences.

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In the Atlantic Ocean circulation, the relatively warm and salty surface water near the equator flows toward Greenland. During its journey it crosses the Caribbean Sea, loops up into the Gulf of Mexico, and then flows along the U.S. East Coast before crossing the Atlantic.

How the Atlantic Ocean circulation changes as it slows. IPCC 6th Assessment Report

This current, also known as the Gulf Stream, brings heat to Europe. As it flows northward and cools, the water mass becomes heavier. By the time it reaches Greenland, it starts to sink and flow southward. The sinking of water near Greenland pulls water from elsewhere in the Atlantic Ocean and the cycle repeats, like a conveyor belt.

Too much fresh water from melting glaciers and the Greenland ice sheet can dilute the saltiness of the water, preventing it from sinking, and weaken this ocean conveyor belt. A weaker conveyor belt transports less heat northward and also enables less heavy water to reach Greenland, which further weakens the conveyor belt's strength. Once it reaches the tipping point, it shuts down quickly.

What happens to the climate at the tipping point?

The existence of a tipping point was first noticed in an overly simplified model of the Atlantic Ocean circulation in the early 1960s. Today's more detailed climate models indicate a continued slowing of the conveyor belt's strength under climate change. However, an abrupt shutdown of the Atlantic Ocean circulation appeared to be absent in these climate models. <https://www.youtube.com/embed/p4pWafuvdrY?wmode=transparent&start=0> How the ocean conveyor belt works.

This is where our study comes in. We performed an experiment with a detailed climate model to find the tipping point for an abrupt shutdown by slowly increasing the input of fresh water.

We found that once it reaches the tipping point, the conveyor belt shuts down within 100 years. The heat transport toward the north is strongly reduced, leading to abrupt climate shifts.

The result: Dangerous cold in the North

Regions that are influenced by the Gulf Stream receive substantially less heat when the circulation stops. This cools the North American and European continents by a few degrees.

The European climate is much more influenced by the Gulf Stream than other regions. In our experiment, that meant parts of the continent changed at more than 5 degrees Fahrenheit (3 degrees Celsius) per decade - far faster than today's global warming of about 0.36 F (0.2 C) per decade. We found that parts of Norway would experience temperature drops of more than 36 F (20 C). On the other hand, regions in the Southern Hemisphere would warm by a few degrees.

The annual mean temperature changes after the conveyor belt stops reflect an extreme temperature drop in northern Europe in particular. Ren M. van Westen

These temperature changes develop over about 100 years. That might seem like a long time, but on typical climate time scales, it is abrupt.

The conveyor belt shutting down would also affect sea level and precipitation patterns, which can push other ecosystems closer to their tipping points. For example, the Amazon rainforest is vulnerable to declining precipitation. If its forest ecosystem turned to grassland, the transition would release carbon to the atmosphere and result in the loss of a valuable carbon sink, further accelerating climate change.

The Atlantic circulation has slowed significantly in the distant past. During glacial periods when ice sheets that covered large parts of the planet were melting, the influx of fresh water slowed the Atlantic circulation, triggering huge climate fluctuations.

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So, when will we see this tipping point?

The big question - when will the Atlantic circulation reach a tipping point - remains unanswered. Observations don't go back far enough to provide a clear result. While a recent study suggested that the conveyor belt is rapidly approaching its tipping point, possibly within a few years, these statistical analyses made several assumptions that give rise to uncertainty.

Instead, we were able to develop a physics-based and observable early warning signal involving the salinity transport at the southern boundary of the Atlantic Ocean. Once a threshold is reached, the tipping point is likely to follow in one to four decades.

A climate model experiment shows how quickly the AMOC slows once it reaches a tipping point with a threshold of fresh water entering the ocean. How soon that will happen remains an open question. Ren M. van Westen

The climate impacts from our study underline the severity of such an abrupt conveyor belt collapse. The temperature, sea level and precipitation changes will severely affect society, and the climate shifts are unstoppable on human time scales.

It might seem counterintuitive to worry about extreme cold as the planet warms, but if the main Atlantic Ocean circulation shuts down from too much meltwater pouring in, that's the risk ahead.

This article was updated on Feb. 11, 2024, to fix a typo: The experiment found temperatures in parts of Europe changed by more than 5 F per decade.

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